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Science Breakthroughs to Advance Food and Agricultural Research by 2030

PRESENTED TO BERAC

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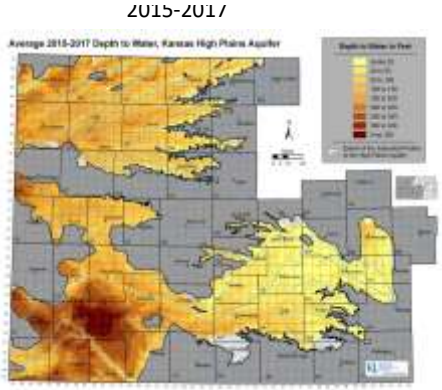
Challenges to the U.S. Food & Agriculture System

- U.S. agriculture & food systems are not efficient, resilient, and sustainable in the face of growing demand and yield plateaus
  - World food production must increase by ~80% to meet needs of projected global population of 8.6 billion by 2030
  - U.S. is losing global competiveness
  - U.S. food security is at risk
  - Climate related stresses
  - Insufficient understanding of **system** interactions



Committee Membership

John D. Floros, *Co-Chair*, New Mexico State University
Susan R. Wessler, *Co-Chair*, University of California, Riverside
David B. Allison, Indiana University
Corrie C. Brown, University of Georgia
Lisa Goddard, Columbia University
Mary Lou Guerinot, Dartmouth College
Janet Jansson, Pacific Northwest National Laboratory
Lee-Ann Jaykus, North Carolina State University
Helen H. Jensen, Iowa State University
Rajiv Khosla, Colorado State University
Robin Lougee, IBM Research
Gregory V. Lowry, Carnegie Mellon University
Alison L. Van Eenennaam, University of California, Davis

What was the committee asked to do?

Statement of Task (see Box 1-2, page 16)

To lead the development of an innovative strategy for the future of food and agricultural research, answering the following questions:

1. What are the greatest challenges?
2. What are the greatest scientific opportunities?
3. What are the most important knowledge gaps?
4. What general areas of research can fill these knowledge gaps?

What was the committee's approach?

- Information Gathering & Input (in 2017)
  - Meetings (57 speakers/invited participants)
    - 1st: June 14-15
    - 2nd (Public Town Hall): August 8-9
    - 3rd (Workshop): October 2-6
    - 4th Meeting: November 14-15 (closed for deliberations)
  - ideabuzz Online Discussion Platform (79 submitters)
  - Webinars on: food science, phosphorus, water, sensors, and urban agriculture

What was the committee's approach? (cont'd)

- Considered a time horizon of **2030**
  - Determine the most challenging issues in food and agriculture that can be addressed by science
  - Identify science breakthroughs necessary to meet the challenges
  - Scope
    - U.S. centric issues, recognizing global impact
    - Outside: food distribution and access, human health, **biofuels**, and policy

Committee's Findings and Conclusions

Most Challenging Issues

- **reducing soil loss and degradation;**
- **optimizing water use in agriculture;**
- **increasing nutrient use efficiency;**
- **mobilizing genetic diversity for crop resilience;**
- early and rapid detection and prevention of plant, animal and foodborne diseases
- improving food animal genetics;

Opportunities for the Future

- Major scientific advances in the past decade provide new opportunities to solve the most vexing challenges facing food and agriculture
  - Chemistry, biology, materials science, engineering
  - Genetics, sensing, computing, data science, wireless technologies, internet, microbiome

- *Convergence* of these advances with social and behavior science can afford new systems-based approaches to make agriculture more *efficient*, *resilient*, *and sustainable*.

Major goals for food & agricultural systems for 2030

(1) improving efficiency,

(2) increasing resiliency to adapt to rapid changes and extreme conditions, and

(3) increasing sustainability.

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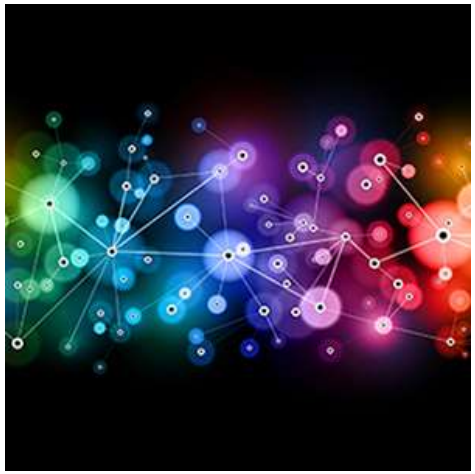
Convergence

- Integration of knowledge, tools, and ways of thinking to identify novel transdisciplinary solutions to complex problems facing food and agriculture

  - New ways to formulate the questions to provide holistic solutions

NSF 10 Big Ideas



Organization of Chapters by Areas

- Crops (Chapter 2)
- Animal Agriculture (Chapter 3)
- Food Science and Technology (Chapter 4)
- Soils (Chapter 5)
- Water-Use Efficiency and Productivity (Chapter 6)
- Data Science (Chapter 7)
- A Systems Approach (Chapter 8)

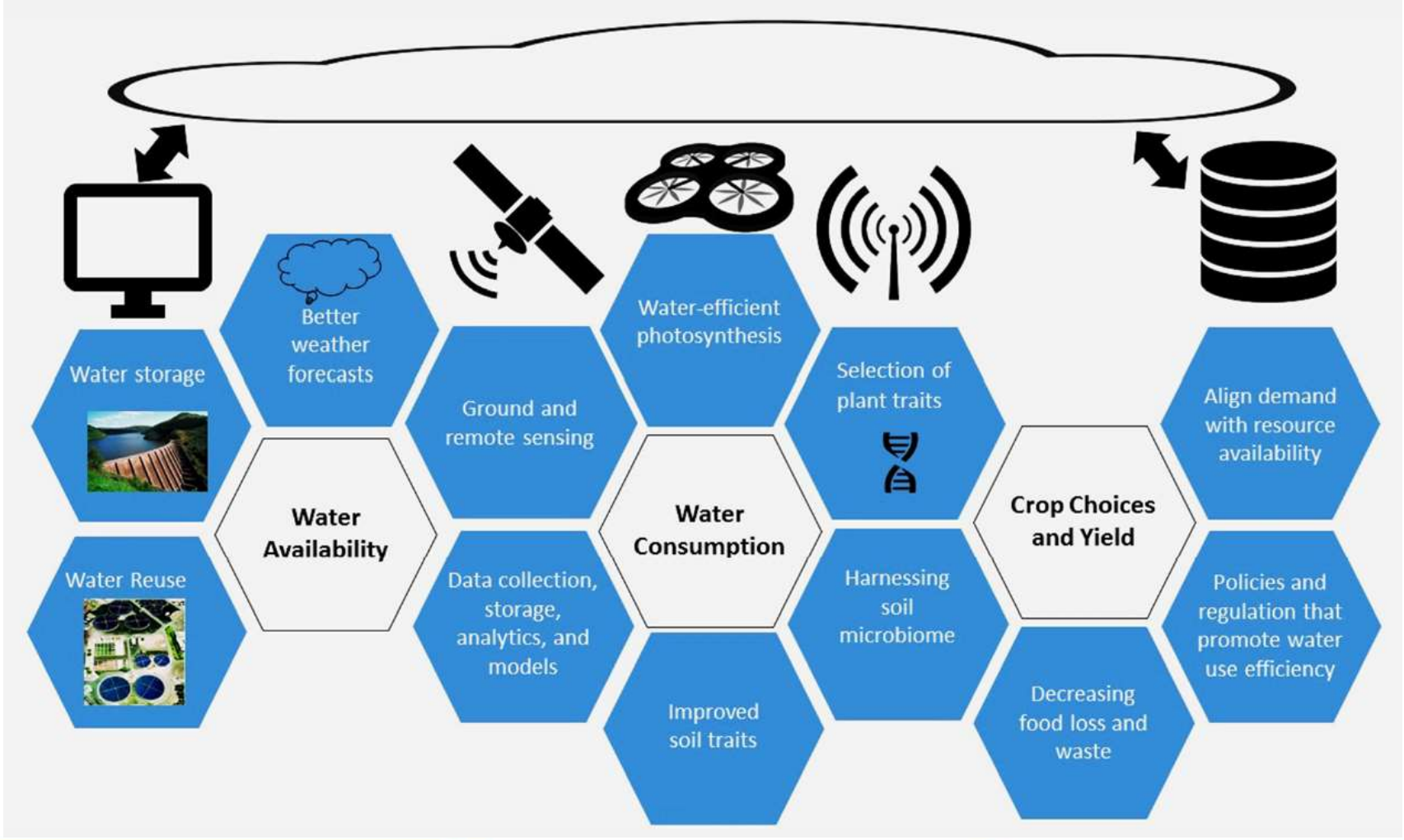
Science Breakthroughs & Recommendations

Transdisciplinary Research & Systems Approach

- **Breakthrough 1:** A systems approach to understand the interactions among the different elements of the food and agricultural system that can be leveraged to increase overall system efficiency, resilience, and sustainability.

- **Recommendation 1:** Transdisciplinary science and systems approaches should be prioritized to solve agriculture's most vexing problems.

Convergent Approach to Water Management



Box 9-1 p. 118

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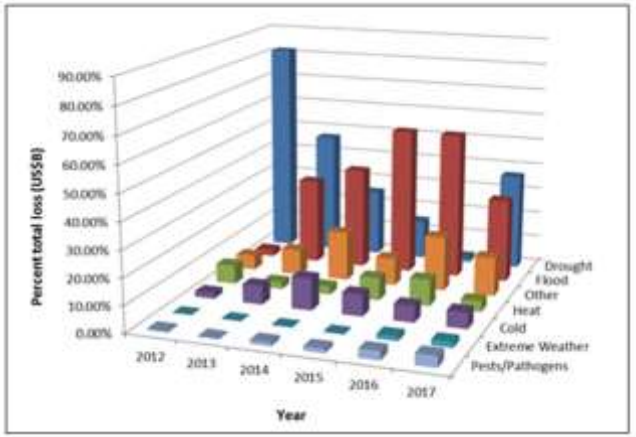
Sensing Technologies

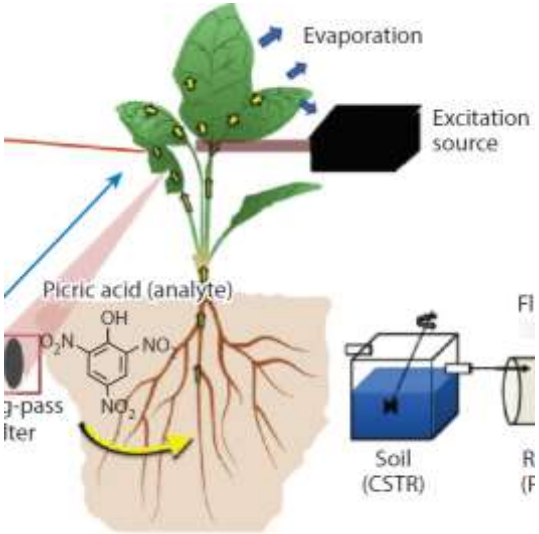
- **Breakthrough 2:** The development and validation of precise, accurate, field-deployable sensors and biosensors will enable rapid detection and monitoring capabilities across various food and agricultural disciplines.

- **Recommendation 2:** Create initiatives to more effectively employ existing sensing technologies and to develop new sensing technologies across all areas of food and agriculture.

Sensing Opportunities

- <u>Continuous</u> monitoring of environmental stimuli and biotic and <u>abiotic</u> stresses.
  - Soil and plant moisture and nutrient contents
- Detect disease before it manifests
  - Plants as sensors





Kwak et al., 2017

Data Science and Agri-Food Informatics

- **Breakthrough 3:** The application and integration of data sciences, software tools, and systems models will enable data-driven approaches for managing the food and agricultural system.
- **Recommendation 3:** Establish initiatives to nurture the emerging area of agri-food informatics and to facilitate the adoption and development of information technology, data science, and artificial intelligence in food and agricultural research.

Genomics and Precision Breeding

- **Breakthrough 4:** The ability to carry out routine gene editing of agriculturally important organisms will allow for precise and rapid improvement of traits important for productivity and quality.

- **Recommendation 4:** Establish an initiative to exploit the use of genomics and precision breeding to genetically improve traits of agriculturally important organisms.

Opportunities in Gene Editing

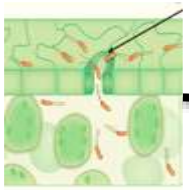
- Gene editing—aided by recent advances in genomics, transcriptomics, proteomics, and metabolomics will improve efficiency, resilience, and sustainability by
  - Speeding the selection of alleles without linkage drag to enhance productivity, resilience, nutritional value
  - Domesticating new crops and soil microbes
  - Mining biodiversity for useful genes
  - Creating dynamic (responsive) crops (Park et al., 2015)
  - Converting C3 systems to C4 systems
  - Synthetic biology to optimize plant-microbe interactions

Microbiome

- **Breakthrough 5:** Understanding the relevance of the microbiome to agriculture and harnessing this knowledge to improve crop production and increase resilience to stress and disease.

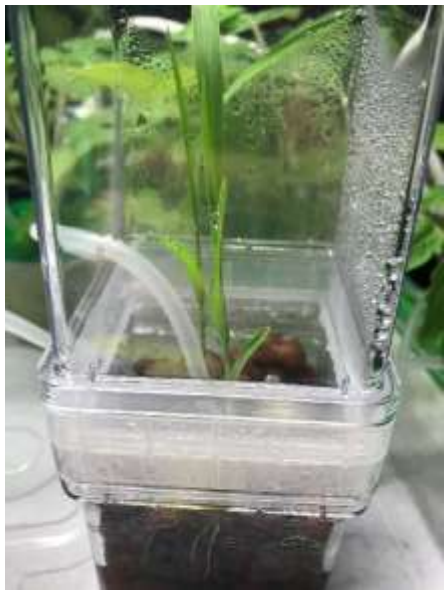
- **Recommendation 5:** Establish an initiative to increase the understanding of the animal, soil, and plant microbiomes and their broader applications across the food system.

Origins of the Plant Microbiome



ATMOSPHERE

SOIL



SEED

Desirable traits

Interagency Strategic Plan for Microbiome Research FY 2018-2022 (April 2018)

Promising Research Directions for Achieving Goals

(see Report Box S-1, on pages 6-7)

Alignment with DOE Bioenergy Centers

CABBI
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→ Design improved dedicated bioenergy crops.

JBEI
Joint BioEnergy Institute

→ Optimize water and nutrient use in dedicated bioenergy crops.

Create multiomics tools for developing high-yield bioenergy crops.

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→ Study environmental resilience of engineered bioenergy crops

Engineer plants for atom-economical conversion into biofuels and bioproducts.

GREAT LAKES BIOENERGY RESEARCH CENTER

→ Develop “plants as factories” concept for biofuels and bioproducts.

Further Considerations for Implementation

- Research Infrastructure
  - Investments are needed for tools, equipment, facilities, and human capital
- Education and Scientific Workforce
  - Renew interest in food and agriculture to engage non-agricultural professionals and to excite the next generation of students.
- Funding
  - Current public and private funding for food and agricultural research is inadequate to address critical breakthrough areas over the next decade.

Questions?

Thank You

Study sponsored by

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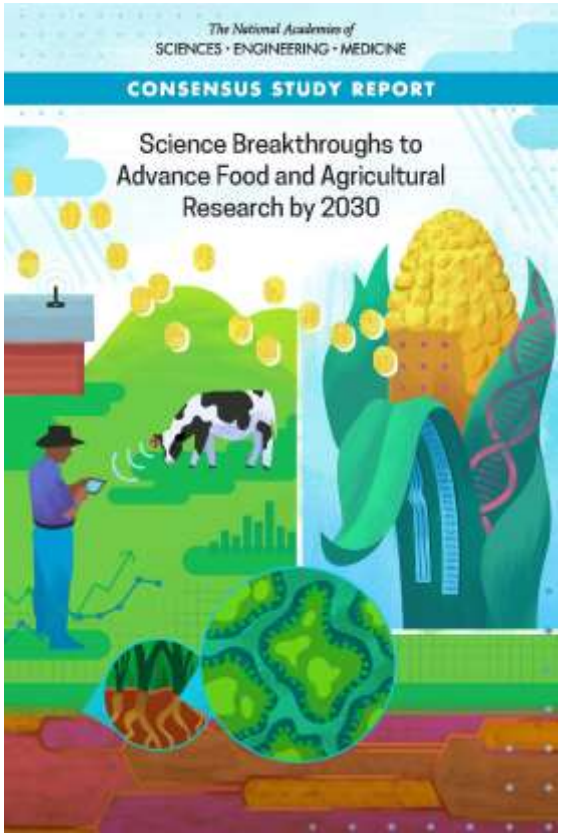

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